LACCOLITES IN SOUTHEASTERN COLORADO.[1]

THE western part of Colorado is mountainous; the eastern belongs to the Great Plains. The plains are in part smooth, as the name implies, and in part broken by canyons and diversified by valleys, cliffs, and terraces. Near the southeast corner of the state is a broad upland plain, bounded on the north, south, and west by bluffs that overlook lowlands with diversified relief. The plain slopes gently toward the east and is furrowed here and there by streams flowing in the same direction. Its determining formation is an alluvial deposit of sand and gravel, believed to be of Neocene Age. This rests on an eroded surface of Cretaceous and Juratrias rocks, and these rocks are exposed in the surrounding lowlands as well as in the channels of the dissecting streams.

Previous to the modern dissection the alluvial plain must have been remarkably even, but a few knobs of resistant rock projected above it, and one of these now stands so high as to constitute a conspicuous landmark. Twin Butte, or Two Buttes as it is sometimes less aptly called, is conical in its general form but has a double summit. Past its southern base flows Two Butte Creek, and the rock exposures are continuous from the butte to the creek. The crest of the butte is 350 feet above the plain and 600 feet above the creek. It stands in west longitude 102° 33′ and north latitude 37° 39′.

Visiting the locality in September 1895, I found the butte to be capped by a block of sandstone which had acquired exceptional hardness through association with a local occurrence of igneous rocks; and a hasty examination of neighboring exposures discovered such an arching of the Mesozoic strata as to

[1] The observations here communicated were made in connection with field work of the U. S. Geological Survey, and are published by permission of the director.

Proof of this article has not been read by the author.—ED.

indicate the presence of laccolites of some magnitude. The following month I returned to the locality in company with Mr. F. H. Newell, and we spent a week in local surveys and studies. A contour map of the locality was made, the thicknesses of the sedimentary formations were measured, and all outcrops were platted. By combining these data it was found possible to construct an approximate contour map of the deformation of the upper strata, and thus estimate the total volume of the intrusions.

The following is the sedimentary section as determined by Mr. Newell:

5. Olive, purple, and pink shales, with beds of fine-grained yellow sandstone, and one or more bands of concretionary impure limestone. The sandstone contains large, beach-rolled, silicified logs. From the upper shaly layers were obtained invertebrate fossils, recognized by Mr. T. W. Stanton as of Dakota age. The top of the formation was not seen, - - - - - - - - 100 ft.

4. Sandstone, fine-grained, chiefly massive but partly bedded, of variable color. On the east side of the dome all zones of the sandstone are bright red, and this is probably their normal color; but the different layers, as they approach the base of the Neocene sands, become yellow, and in some places white. On the southwestern slope of the dome, a shale forty or fifty feet thick parts the sandstone into two groups, of which the lower retains the characters just described, while the higher has a prevailing dull yellow color, and is in part vitreous, as though modified by igneous intrusion. A similar distinction was seen at the north, where most of the upper member has the character of quartzite, and the yellow color is replaced by gray, - - - - - - - 380 ft.

3. Brick-red shales, arenaceous at top and passing by gradual transition into No. 4. Soft and easily eroded, except in the immediate vicinity of igneous masses, - - - - - - - - 150 ft.

2. White limestone, - - - - - - - - - - 5 to 10 ft.

1. Yellow, red, and orange, thin-bedded shales and sandstones. The shales probably exceed the sandstones in thickness, but being largely arenaceous, they assume the character of sandstones in the vicinity of igneous intrusions. The bottom of the series was not seen, - - - - - - - - - - - - 100 ft.

Total, - - - - - - - - - - - - 740 ft.

No fossils were found below No. 5, and our present knowledge of the general stratigraphy of the surrounding country does not warrant a definite correlation of the formations. A few miles farther north the Dakota formation is exposed in a broad belt, beyond which it dips under the Benton shales.

Two Butte Creek, which in general has a comparatively open valley, passes at this point through a box canyon sixty feet deep, and in the walls of the canyon the three highest formations are seen to arch regularly from west to east. They are also seen to dip southward, so that the structure revealed by the canyon is essentially part of a quaquaversal arch. Scattering outcrops of various formations at the north accord with this theory, and further confirmation is found in the vicinity of the butte, where some of the highest ground, excepting the butte itself, is occupied by the lowest formation, No. 1. The white limestone (2), which outcrops in the creek valley with southerly dip, is also found at the southeastern base of the butte, where it is nearly level; and the crest of the butte consists of the lower division of the red sandstone (4) which there dips to the west. By combining the stratigraphic and hypsometric data it was found possible to estimate at many points on the sheet the height to which the upper formations had been lifted; and with further aid from observed dips, contour lines were drawn to represent the figure of deformation. These contours appear in Fig. 5, where a distinction has been made between the parts practically fixed by the observed data and other parts interpolated with a free hand. So many minor inflections were found in the district exposed to direct study that we may suppose the actual contours to be much less regular than those supplied for the regions covered by the Neocene sands. At several points there are local flexures, giving dips of fifteen or twenty degrees, and it is probable that a fault traverses the western slope of the butte.

The formation thus determined has a basal breadth in any direction of from five to five and a half miles. Its central height is from 1000 to 1200 feet, the smaller estimate being derived from the northwestern slope, the greater from the eastern

and southeastern slopes. In neighboring regions the Cretaceous formations are characterized by flexures and dislocations of minor importance, and it is probable that a deformation of that general character is here combined with the arching due to igneous intrusion. A computation based on the contours of deformation indicates the total volume of the uplifted or protuberant mass as a little less than one cubic mile.

The igneous rocks associated with this local uplift include laccolites and dikes. There are at least two laccolites, and the number may be much larger. The highest is known only by a remnant exposed at various points about the southeastern base of Twin Butte where it rests on the white limestone (formation 2) and is covered by red shale (3). It does not appear on other sides of the butte, and it is probably limited on the west by a fault. The steep westward dip of the overlying strata suggests that the mass may originally have been large. Beneath it, and separated only by the white limestone, is a broad mass whose upper parts only are seen. Its outcrop is nearly continuous for three-fourths of a mile from north to south and more than half a mile from east to west. Wherever its relations to the sedimentaries are seen it passes beneath them, the overlying strata being either formation 2 or some member of formation 1. South of this area is a smaller tract of igneous rock which may represent a laccolite or a sill; and beyond it is the irregular exposure of an intrusive mass which ranges in thickness from fifteen or twenty to more than 100 feet and traverses the formation obliquely so as to be walled in places by formations 1, 2, and 3. It is possible that the larger of the observed laccolite masses is the principal intrusion, occupying practically the whole interior of the dome; but consideration of the irregularities of the deformation leads rather to the view that the arch includes a number of individual masses.

About fifty dikes were noted traversing parts of the dome, and it is probable that others intersect the laccolites. One dike was seen at a point two miles beyond the northwest base of the dome, and at another point outside the dome a well sunk through

the Neocene sand brought up igneous rock of the same general type. The majority of the dikes trend approximately at right angles to the strike, so that if produced they would pass near the center of the uplift; but on the southwestern slope of the dome a small group trend approximately with the strike.

In the various characters thus far mentioned the Twin Butte laccolites do not differ from the ordinary type, but petrographically they are rather exceptional, and their peculiarity of rock type is the occasion of geomorphic characters which are equally notable.

Classifying igneous rocks broadly as basic, intermediate, and acid, most of the laccolitic rocks heretofore described belong to the intermediate group, a smaller number are acid, and basic examples are comparatively unknown. R. C. Hills characterizes as doleritic two small masses observed in Huerfano Park, Colorado,[1] and Weed and Pirsson have described large laccolitic masses, occurring in the Highwood, Little Belt, and Bearpaw mountains of Montana, in which the outer parts are basic and the inner acid.[2] The Twin Butte rocks also are basic and closely resemble some of the Montana types. As the chief mass is so little dissected that all collections were from the upper part, it is quite possible that the new locality belongs structurally with the type discovered by Weed and Pirsson.

The specimens collected have been placed in the hands of Mr. Whitman Cross and are to be studied in connection with cognate rocks obtained by myself and others from a great system of dikes occurring in areas to the west and south of the locality under consideration. As the result of a preliminary examination he informs me that they are properly designated syenite-porphyry. The essential constituents are biotite, augite, and alkali feldspars, and as the ferro-magnesian minerals predominate, the rocks are basic. They are porphyritic in structure, and large phenocrysts of biotite are characteristic.

[1] Proc. Colorado Scientific Soc., Vol. III, Part 2, p. 226, 1889.

[2] Bull. Geol. Soc. Am., Vol. VI, pp. 389–422 (1895); Am. Jour. Sci., 3d ser., Vol. L, pp. 467–479 (1895); 4th ser., Vol. I, pp. 283–301, 467–479 (1896). The authors refer also to descriptions of European localities.

Fragments of various rocks are included in the laccolites and dikes, and are of interest as revealing the nature of lower-lying terranes through which the ascending liquid passed. Besides sandstones and shales similar to those constituting the wall rocks, the most abundant as well as the most notable rock is a porphyritic granite with conspicuous crystals of gray feldspar.

The age of the laccolitic intrusion is not closely determined. The youngest formation involved in the deformation is the Dakota. The Neocene sand rests undisturbed on the worn edges of the deformed strata. Manifestly the intrusion was subsequent to the one and antecedent to the other. These limits stand wide apart, but a little consideration will show that the epoch of intrusion was probably not close to either. In discussing the laccolites of the Henry Mountains, the writer reached the tentative conclusion that a heavy load of overlying rocks was a condition essential to the formation of a large laccolite, and the body of data which has since been gathered is rather confirmatory of this conclusion than otherwise. If this be admitted we must assign to the intrusion a date at which the Dakota sandstone was covered to a great depth by other formations. It is known from the general history of the region that the deposition of the Dakota was followed by that of the Colorado and Montana groups, and it is possible that these were here succeeded by the Laramie also. Subsequently all these beds were eroded, not only from this particular district but from an extensive tract of the Great Plains province, and much time was necessarily consumed in this work. It seems therefore probable that the date of the igneous intrusion belongs either to the closing epochs of the Cretaceous period or to the earlier half of the Eocene period.

The porphyrites and cognate rocks which elsewhere constitute the greater number of laccolitic masses are notable for their durability. Not only are they so hard as to resist corrasion stubbornly and cause the diversion of such small streams as may chance to flow athwart them when they are discovered by the general degradation of the country, but they yield with

extreme slowness to the ordinary processes of disintegration. It results that in regions of rapid degradation laccolites usually survive all associated rock-masses and find topographic expression in steep-sided mountains or buttes. In these respects the rock of the Twin Butte locality is strongly contrasted. It weathers more easily than the associated sandstone, so that dikes traversing sandstone outcrops are sometimes not easy to trace; and it is scarcely more durable than the associated shales. The dikes do indeed stand prominent above shale areas, but this is occasioned largely by the baking of the shales along the planes of contact, and also in part by an alteration of undetermined character which in some instances affects the dike rock for a few inches from the planes of contact. Where the laccolites are in contact with shales the latter are modified for many feet or yards, being rendered much more durable than the igneous rock. It results that the exposed parts of laccolites, being weaker than all the associated sedimentaries, are characterized topographically by valleys.

I. C. Russell, reasoning from the dominance of acid rocks among laccolites, the frequent occurrence of basic rocks as thin sheets, and the viscosity of acid magmas as compared to basic at the same temperatures, has recently suggested[1] that great viscosity is an essential condition of the production of thick intrusive lenses. As this theory encounters serious difficulty in the new data from Montana and southeastern Colorado, I venture an alternative suggestion involving a different point of view. The topographic features associated with the weak basic rocks at Twin Butte are inconspicuous, whereas those of the resistant porphyrites of the Elk and Henry mountains are bold and striking. Is it not possible that the basic rocks are really well represented in laccolites, but have as yet received little notice because in the gradual development of the subject the more salient features have first caught the eye?

G. K. GILBERT.

[1] JOUR. GEOL., Vol. IV, pp. 179–180, 1896.

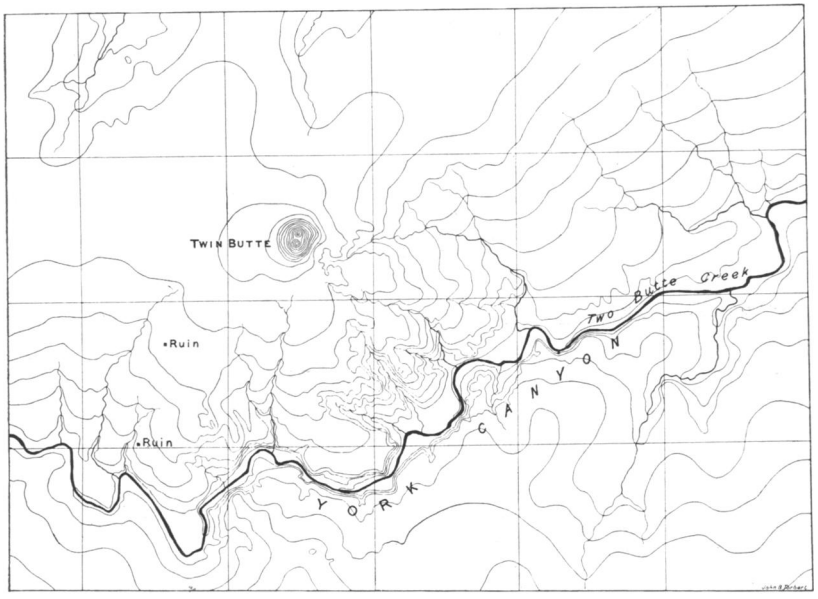

FIG. 1.—Topographic map, contour interval, 25 feet.

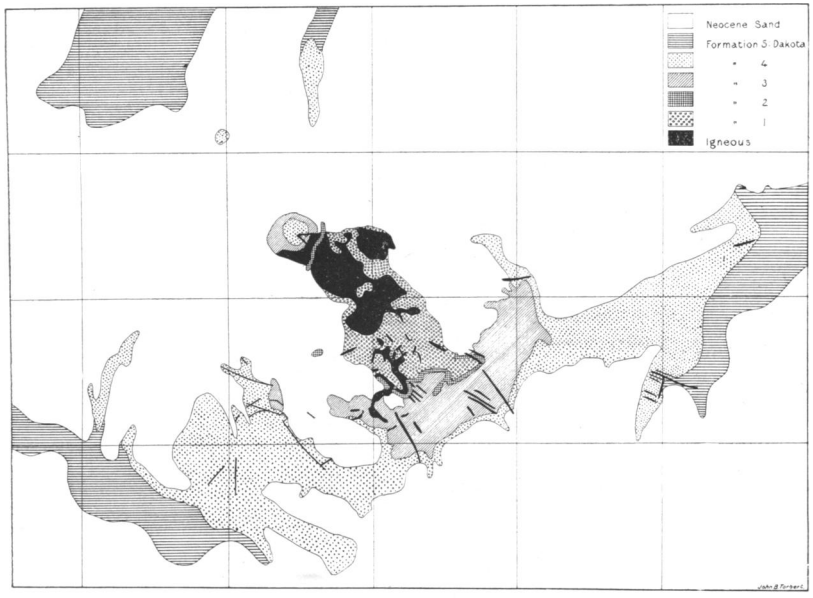

FIG. 2.—Geologic map of same area. Laccolites in southeastern Colorado.

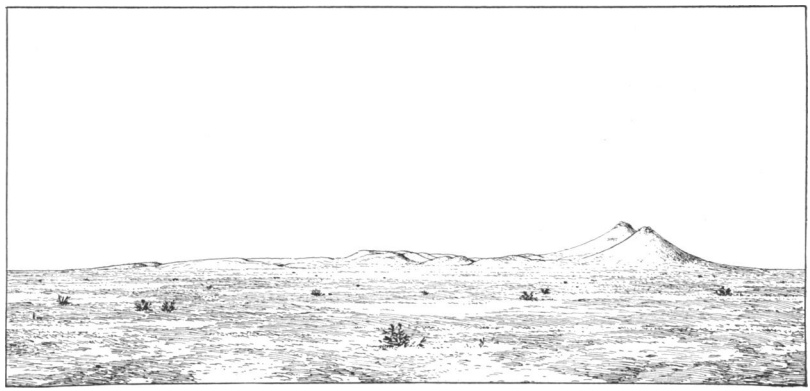

FIG. 3.—Twin Butte and the crest of the arch, from a point on the plain two miles northeast.

FIG. 4.—Ideal cross-section of igneous intrusion.

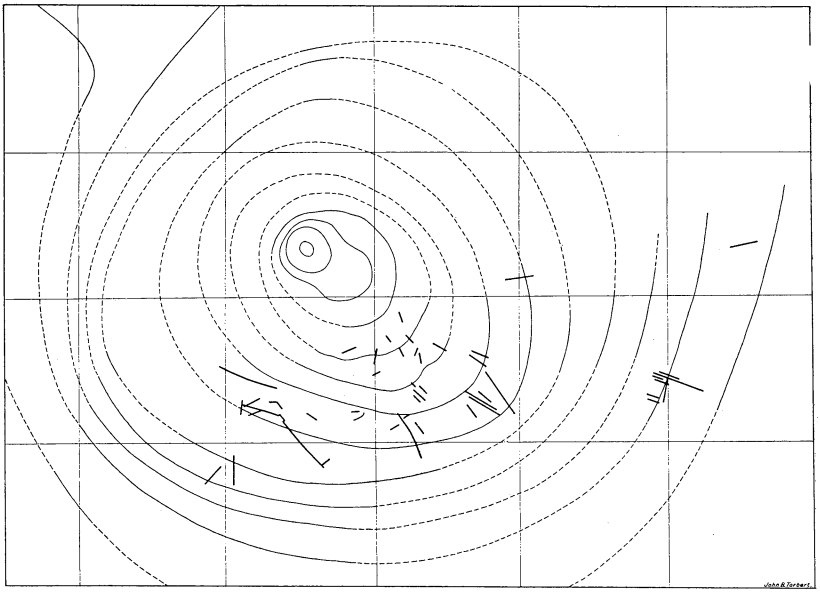

FIG. 5.—Deformation map. See explanation at end of text. Laccolites in southeastern Colorado.

EXPLANATION OF FIGURES.

All of the figures except the landscape view have the same scale. Each of the three maps represents the same area. To aid in their comparison vertical and horizontal lines are drawn at intervals corresponding to one mile.

FIG. 1. Map of Twin Butte and vicinity, showing the topographic relief by contour lines at every 25 feet.

FIG. 2. Geologic map of Twin Butte and vicinity, showing the distribution of the surface formations described in the text.

FIG. 3. Landscape. In the foreground the plain of Neocene alluvium. At the right, Twin Butte. At center and left, the crest of the laccolitic dome, dissected by drainage flowing in the direction from the observer and descending rapidly to Two Butte Creek. The rocks capping these low hills are shales hardened by reaction from the laccolite beneath.

FIG. 4. Ideal cross-section of the igneous intrusion, from east to west. The profile of this is constructed from the contours of deformation (Fig. 5) on the assumption that the intrusives constitute a continuous mass dividing the sedimentaries at a single horizon. It is known that this assumption is not strictly true, but the meager data at command do not suggest an improvement. The diagram shows for each point the total uplift of the cover and therefore the total thickness of intrusive rock.

FIG. 5. Deformation map of Twin Butte and vicinity, showing, by means of contours at intervals of 100 feet, the form which would appear if the eroded parts of formation 3 (Fig. 2) were restored, and all overlying formations were removed. Where the positions of the contours are controlled by the geologic data the lines are full. The broken lines are interpolated. The other lines of the figure mark the position and trend of dikes.